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Improving the Traversal of Large Hierarchical Process Repositories

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Abstract

Business Process Management (BPM) has increased in popularity and maturity in recent years. Large enterprises engage use process management approaches to model, manage and refine repositories of process models that detail the whole enterprise. These process models can run to the thousands in number, and may contain large hierarchies of tasks and control structures that become cumbersome to maintain. Tools are therefore needed to effectively traverse this process model space in an efficient manner, otherwise the repositories remain hard to use, and thus are lowered in their effectiveness. In this paper we analyse a range of BPM tools for their effectiveness in handling large process models. We establish that the present set of commercial tools is lacking in key areas regarding visualisation of, and interaction with, large process models. We then present six tool functionalities for the development of advanced business process visualisation and interaction, presenting a design for a tool that will exploit the latest advances in 2D and 3D computer graphics to enable fast and efficient search, traversal and modification of process models.

Keywords

Business Process Modelling, Tools, Visualization.

INTRODUCTION

In recent years, the conceptual mapping of processes in the form of process models has emerged as a primary reason to engage in conceptual modelling (Davies et al. 2006) and is considered a key instrument for the analysis and design of process-aware information systems, organizational documentation and re-engineering, the design of service-oriented architectures, web services and other IS application areas (Recker et al. 2009). Process models typically describe in a graphical way at least the activities, events/states, and control flow logic that constitute a business process. Additionally, process models may also include information regarding the involved data, organizational and IT resources, and potentially other artefacts such as external stakeholders and performance metrics (e.g., Scheer 2000).

Process models are designed using so-called process modelling grammars (sometimes called notations or techniques), i.e., sets of graphical constructs and rules how to combine these constructs. Such grammars are widely available and differ considerably in terms of 'how' process models can be designed (Rosemann et al. 2006). These process modelling grammars are implemented, and being used, as part of a process modelling tool, or even a business process management tool suite (Hill et al. 2007). Some of these tools have, over the years, become mature and sophisticated and complement a typical graphical model editor with extended functionality enabling simulation, reporting, analysis or even execution of the process models stored (Recker et al. 2006).

The maturity of available tools brings with it the opportunity to model comprehensively large scale enterprises. Repositories are created of process models detailing the entire enterprise, with processes decomposed into hierarchies, from high level value chain diagrams down to work instructions detailing atomic tasks performed within the organisation (Davis 2001). Anecdotal evidence as well as case studies report on organizations having repositories storing hundreds and thousand process models in different variants, releases, details and versions. This phenomenon is called modelling in the large (Raduescu et al. 2006).

Process modelling in the large brings about a range of issues, such as, for instance, the appropriate visualization of large-scale, detailed process models, the proper decomposition of process model hierarchies, or – more generally – the ease of process model repository traversal to support modelling tasks. A business analyst that is seeking to model a business process needs to understand the context of the process, and its relationship to other processes in the system. For this reason, process modelling grammars are sought to support process decomposition and process structuring through appropriate representational constructs. However, a recent review (Recker et al. 2009) showed that most grammars in use today lack adequate support for modelling in the large. In consequence, one would expect that process modelling tools offer extended functionality to allow for the efficient traversal of large process repositories. Yet, the issue of organisation and traversal of process hierarchies continues to be only dealt with in an ad-hoc manner using the tools available (Streit, Pham and Brown 2005). This situation is surprising given the recent advances in tool usability and functionality that stem from related reference discipline such as interaction design (Cooper, Reimann and Cronin 2007), user interface design (Shneiderman and Plaisant 2004) or data visualization (Munzner 1998; Hughes, Hyun and Liberles 2004).

The objective in writing this paper is to examine the state of the art in large process model visualisation and traversal as implemented in market-leading process modelling tools, and to propose, based on our findings, a number of key tool features to facilitate advanced large process model traversal and visualisation, utilising the latest techniques in graph visualisation, interaction design and user interface design, to enable the visualisation of large models within deep process model hierarchies.

We proceed as follows. The next section details the motivation for designing good large process oriented interfaces in process modelling tools. Then, we report on our comprehensive analysis of five tools drawn from industry rankings as the most popular process modelling tools. Next, we suggest, based on the analysis conducted and a review of recent advances in related disciplines, a number of key visualisation and traversal features that process modelling tools should support. We present a proof-of-concept prototype as an illustrative example for next generation tool support for large process model traversal. The paper then concludes with recommendations for future work.

BACKGROUND

Process models created in some sort of grammar – such as, for instance, EPCs (Scheer 2000) – are essentially bipartite graphs illustrating the tasks, choices and events that occur within the enterprise. These process models come in different forms (Recker et al. 2009) but all essentially build upon the promise of helping people to understand their business processes.

Yet, in correspondence with increasing organizational complexity, the models that reflect organizational procedures, involved resources, governing policies and regulations, supporting data and systems infrastructures etc., grow to a size of considerable complexity quite quickly. A typical business process model captures the main variants of a business process, the involved applications, organisational units, data, knowledge, business partners as well as related policies and manuals. Therefore, process models can grow large, as does the number of process models typically stored in a process modelling tool. This situation brings forward challenges to the user interface design of these tools, to allow users to model quickly and easily, and to be able to retrieve quickly and easily any information from the set of models stored, and to manage the complexity of large-scale process models.

User interface (UI) design is a major component of the usability of any IT-based tool, and – clearly – of any business modelling tool. Shneiderman and Plaisant (2004) claim that a good graphical user interface (GUI) design can reduce anxiety and make users feel more comfortable with the application. Galitz (2007) state that good UI and screen design improve the productivity of users by about 20% in addition to users tending to make less mistakes. Cooper et al. (2007) mention that visual interface design concerns clear communication: "the root of interface design is concerned with the treatment and arrangement of visual elements to communicate behaviour and information." Significant benefits for users of business modelling software would logically follow, if the interface to such systems is improved, especially for those new to modelling. This is because process modelling, in its essence, relies exactly on the premise of using visual elements to describe and communicate organizational behaviour and associated information flows.

And indeed, the importance of adequate tool support to the act of process modelling – especially in large, enterprise-wide, initiatives is well-recognized (Raduescu et al. 2006). Appropriate tool support is named to be key to successful process modelling (Bandara, Gable and Rosemann 2005), and selecting the wrong modelling tool for an organisation may turn out to be a critical impediment to project success. Also, experts claim that current tools lack support for visualising the process at different levels in a hierarchy, and especially large scale models (Indulska et al. 2006).

There is little research being conducted on the nature, functionality or usage of the tools used to support process modelling tasks. Studies from object-oriented modelling disciplines report wide disparities in tool usage (Iivari 1996) and lament lacking adoption of tool functionality in practice (Howard and Rai 1993). Gorla et al. (1995) even report that tabular tools are preferred over graphical tools when representing information in systems analysis and design. However, since the mid-nineties, many new approaches and tools have emerged so that these findings may be of limited value to understanding current and future process modelling.

Hall & Harmon (2007) state that there is no "perfect" tool; the vendor of each tool builds it to support different users, standard notations, and frameworks. The tool that is built for a manager may be simple and easy to use, while the tool for business analysis would provide more features and require some knowledge on how to use it.

Thus, organisations have to choose tools based on their purpose; for instance, their choice may be between a standardized tool suite, or a specific modelling editor.

We argue that good visualisation and user interface design, if available in process modelling tools, would assist modellers considerably in enhancing the effectiveness and efficiency of their process modelling tasks, especially if the process model is large, complex and hierarchically deep. For instance, the modeller should be provided the ability to traverse the repository hierarchy with ease to identify the right process at the right level of detail or to identify inter-related processes, both horizontally and vertically. Our contention is, however, that state-of-the-art process modelling tools currently available on the market have only little consideration of UI design issues. To prove our 'hunch' we thus report next on our analysis of the user interface and visualization capabilities of five market-leading process modelling tools.

TOOL ANALYSIS

Research Approach and Setting

Bandara et al. (2005) claimed that the market for currently available Business Process Management tools is relatively fragmented because different vendors specialise in different aspects of the BPM life cycle (e.g., organizational documentation versus workflow engineering). Depending on the nature of the process model application task, thus, the requirements towards adequate tools support, and tool design, may change considerably. Abstracting from these process model application tasks, in a typical process modelling setting, a tool user occupies roles such as creating, modifying, analysing, verifying the model, and maybe even simulating a model (Frederiks and van der Weide 2006). In general, we identify the following typical tasks that should be adequately supported by a modelling tool:

1. *Communication*: Develop a process model to represent, explain, or discuss the actual organizational processes.
2. *Simulation*: Use a process model to examine the performance of a process in a setting with different conditions.
3. *Creation and modification*: Build a process model based on information about real processes, and edit the model where required;
4. *Verification*: Test the conformance of a process model against a set of modelling rules.

In our analysis, we focus on the tools that have a database repository and can be used for modelling, analysis, modifying, and simulating a business process. Executable systems (i.e., tools that provide a process execution engine) are not considered here, but it is expected that a slightly modified form of our analysis criteria set can be applied to executable process model systems. We chose a representative set of the most popular business process modelling tools to date, as per the reports of recent market studies and practitioner reports (e.g., Blechar 2007; Hall and Harmon 2007). IGrafx, IBM's Websphere, ARIS by IDS Scheer, and Casewise are listed in the four sources three times, so we selected these tools for further analysis. Telelogic, Microsoft VISIO, Mega International, Proforma Corporation, TIBCO Software, Savvion, and Intalio are listed twice, of which we selected Telelogic's System Architect as a fifth tool due to its relative best ranking amongst these tools and due to its considerable adoption in BPM practice, at least in Australasia (Recker 2010).

Tool analyses can focus on different areas, capabilities, functionalities or issues (Ami and Sommer 2007; Blechar 2007; Hall and Harmon 2007). In our analysis we focused explicitly on the interface design pertaining to large process model hierarchy capabilities of the tools, as this has been identified as a major issue in contemporary large scale modelling projects (Raduescu et al. 2006; Recker et al. 2006).

User Interface design criteria were drawn from theoretical sources to establish what was important regarding the viewing and traversal of large data sets (Shneiderman and Plaisant 2004; Cooper, Reimann and Cronin 2007; Galitz 2007), which mention the most important areas for good visualisation and UI design applications. We focus on the user interface and visualisation features required for large scale models with complex hierarchies (Streit, Pham and Brown 2005). Our literature review resulted in the identification of the following components of user design features, which have long been identified as standard for interactive visualisation of complex information (Shneiderman 1996):

- *Zoom*: manipulation of the scale of a process diagram for analysis of details. When performing analysis tasks on large diagrams, the use of intuitive scaling techniques is vital to speed the process.

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- *Context:* Context is supported in part, but is typically weak in these leading packages. No sense of maintaining context between sections of the process model is offered, as the user jumps to the next location without having a sense of location maintained to avoid confusion. The transitions are discrete, and do not enable the representationof the process model as a whole. A contextual overview is supported in ARIS and in Telelogic, but no direct manipulation of the overview representation is available. ARIS supports the notion of a movable square over the overview image. Telelogic has no interaction with the overview representation, presenting it only as a preview image. Casewise provides no support for models larger than the window.
- *Direct Manipulation:* Models can be directly manipulated in the tools considered, but when it comes to the hierarchy traversal the tools resort to using clickable separate windows. This is related to zoom, relationship and context factors, as the tools analysed did not exhibit the capacity to smoothly interpolate between hierarchy levels while maintaining context and showing the relationships between process model objects. This is the least supported feature.

We show in the following the best approaches to large model visualisation and traversal from the test set. IBM Websphere (see Figure 1) showed the best capabilities regarding large processes, and hierarchy relationships to other components. The IDS Scheer ARIS tool (see Figure 2), on the other hand, shows graphical filtering and overview features, but these are not available for all process modelling tasks.

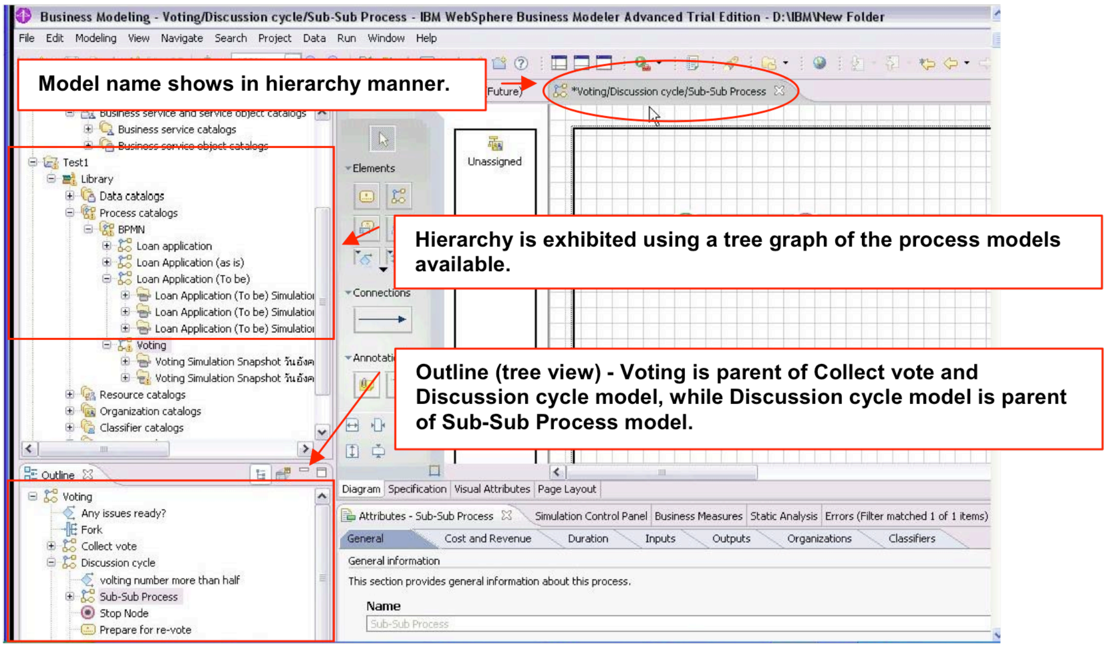

Figure 1: Screenshot of IBM Websphere showing hierarchical representations and traversal capabilities. Each of the boxes and arrows highlight the hierarchy representations and the component based overview of the process model

In conclusion, while each tool has some support for the visualisation and traversal of large process models with deep hierarchies, there is a great lack of filtering, effective context and hierarchy representations, and smooth directly manipulated interfaces for traversing these models. Given the gap of knowledge in the area of process modelling tool research, we thus advance the proposition that latest advances in reference disciplines graph visualisation, interaction design and user interface design can inform better large model traversal through advanced tool features that will ease some of the complications for using such tools. We outline six basic features towards such support in the following.

TOWARDS 3D SUPPORT FOR LARGE PROCESS MODEL TRAVERSAL

Preliminaries

Large unified process models of an entire enterprise are often larger than the software window in which they are drawn. With such limited screen real estate available, it is hard to understand the context of the processes under examination, their relationships to other model components, or their relative position in the hierarchy of all organizational processes. We conjecture from experience gained in other large data set domains (e.g., Hughes, Hyun and Liberles 2004), that the use of non-linear projections can be effective in enabling the detailed examination of sub-processes, while maintaining a sense of context within the model as a whole. This will provide a superior understanding of the relationships between large unified process model components. In essence, these techniques provide the entire enterprise model at a glance, facilitating visual search via a unified model representation that is easy to manipulate.

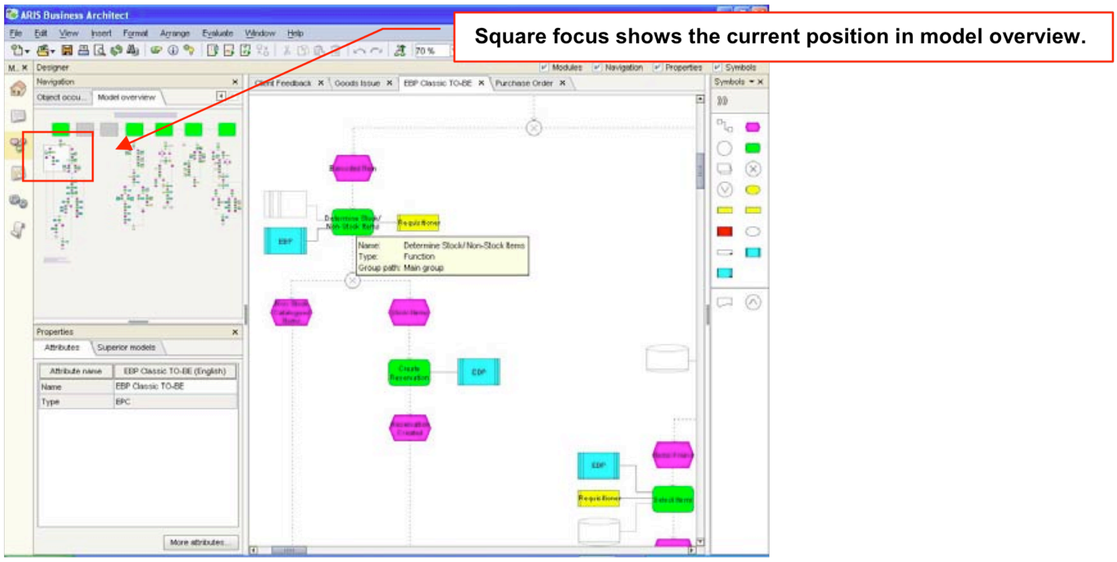

Figure 2: Screenshot IDS Scheer ARIS hierarchy representation and traversal capabilities. The arrow and box highlight the model overview approach used within ARIS. Note that the overview does not allow the user to click to a particular location

An analysis of the benefits of a 3D interfaces is a complex task, which cannot be definitively answered via simple experimentation. The underlying debate is still ongoing regarding the beneficial effects on spatial recall introduced by 3D interfaces. Positive results have been presented showing the superiority of 3D interfaces(Tavanti and Lind 2001), but other papers have emerged questioning the results for 3D static displays (Cockburn 2004). While the research is yet inconclusive and ongoing, we note that the possible display and application scenarios are large, and therefore we should be investigating the possibilities in developing new interfaces for novel domains such as business process modelling.

3D technology facilitates deeper immersion into a model of organizational reality. The additional dimension (depth) can be used describe additional process attributes such as geospatial or time information, which is normally missing from process models. This, in turn, allows to contextualize process models more effectively (Rosemann, Recker and Flender 2008).

Such 3D spaces also offer up greater collaborative possibilities for the development of process model representations, due to the ability to instantiate the remote presence of a collaborator via a 3D avatar, that maps to reality much more effectively than a 2D document offers (Benford et al. 2001). Large process models lend themselves to collaborative modes of creation, flexibly incorporating remote team members via network connections. We believe that these 3D environments offer many real-time collaborative modelling possibilities that are simply non-existent in many present 2D document centric collaboration systems.

Indeed, many information visualisation domains have graph representations with nodes numbering in the many thousands. These application domains often use visual data layout algorithms that use a curved form of Hyperbolic projection of the positions of the graph nodes in 3D, to facilitate easy analysis of the graph contents (Munzner 1998). Such systems require this representation to enhance the ability of the user to visually explore the data for informative patterns. Typical applications of such hyperbolic views include web page analysis (Munzner 1998), bioinformatics (Hughes, Hyun and Liberles 2004) and analysis of computer networks (Pras et al. 2007). Following this idea, three dimensional projections of business process models have recently been developed (Betz et al. 2008), but no one has explored the use of non-Euclidean projection techniques for large enterprise process models. Such non-linear representations of the graph can be applied to the representation of large unified process models, providing a real-time interactive view of the whole enterprise. This is important because an entire enterprise will often have separate process models numbering in the thousands (Raduescu et al. 2006), with tens of thousands of tasks being represented.

If the entire enterprise is to be visualised, then the structural arrangement of the process models must be considered, with an understanding that hyperbolic views of data typically work well with hierarchical data trees.

Such hierarchical trees are also prevalent in process modelling. Standard notations (e.g., BPMI.org and OMG 2006) used in representing enterprise scale process models indeed support such hierarchies, implemented as forms of process decompositions or process architectures, often featuring up to six levels of process hierarchies (Davis 2001). Each of the process models on one of the levels in a process architecture essentially denotes a sub-graph in the overall hierarchy, meaning that each level can be represented as a 3D graph in its own right. This is analogous to the sub-trees contained in hyperbolic projections. Therefore, an entire enterprise becomes a complex structure that benefits from curved space projections, maintaining the benefits of a unified model for browsing and efficient traversal.

Filtering extraneous information from a large, hierarchical process model brings about issues with appropriate rendering of the filtered representations. Aggregation mechanisms have been developed that enable the efficient and balanced representation of a 2D tree at any zoom level (Streit, Pham and Brown 2005; Bobrik, Reichert and Bauer 2007). In these approaches, a final aggregated form is represented that shows a logically correct summary of the graph, sufficient to indicate the nature of the model nodes in which the user is interested.

However, while Hyperbolic views are excellent for the purpose of visualising dense process hierarchies for standard manipulation and editing, as per flat 2D tools; two problems remain from analysis that need to be addressed, these being *semantic understanding* and *collaboration*. To that end, we consider 3D Virtual worlds technology (e.g., Davis et al. 2009) to conjecture that such 3D representations are able to address these issues appropriately.

Previous 3D modelling grammars could potentially encapsulate the control, data and role perspectives of business process models effectively, but often inhibit insight for inexperienced or novice stakeholders in the process model, due to the abstract representation of the 3D modelling. This obfuscation can be alleviated by using more realistic visual representations of a business, as has been shown in other domains, such as virtual factories (Wenzela, Jessen and Bernhard 2005) and mining (Lucas, Thabet and Worlikar 2007). We conjecture that a 3D virtual environment representing the business with embedded process models will help with understanding of complex business systems by stakeholders, by embedding the diagram within a 3D environmental model of the enterprise. Moreover, to address the need for collaborative interfaces for large process model development, traversal and analysis, online 3D virtual environments provide the ability to show the presence of a user in such environments as avatars, in a 3D spatial representation that gives an intuitive interactive space for people to manipulate diagrams and content collaboratively.

In the following, we detail how the prototypes we have developed realize the identified feature component requirements identified through our tool analysis:

- *Zoom*: Zoom controls work by direct manipulation. Standard desktop and laptop systems are now capable of enabling smooth zoom in real time, and thus should also be expected in process model tool user interfaces. What is effective about the 3D representations is that the zoom is spatially uneven, and so regions of interest can be centred for inspection, while still maintaining the periphery for context.
- *Filter*: Filtering can be applied to the levels visible in the model, and the types of nodes shown, at the desire of the user. Sub-processes and nodes types can be filtered out to remove distractions and facilitate traversal and understanding of the process model.
- *Relationship Representation*: Relationship insight is supported by the 3D projections as they enable the entire enterprise to be represented in a unified hierarchical manner in 3D. Process decompositions are represented within a unified tree that enables immediate traversal to sections of interest, and real-time interaction by rotation and examination. As the process model is interactively rotated, it reveals its structure via the relative motion of the model components. Thus, 3D Virtual Worlds can give insight into the spatial context for processes, via embedding them in a visual representation of the enterprise. This capacity, in turn, allows more context-awareness in process modelling (Rosemann, Recker and Flender 2008).
- *Context*: Context is also facilitated, as the user does not have to move their attention to another region of the screen, and so visual attention is maintained on one region, keeping the user engaged (Blackmore et al. 1995). The examination of any node in the graph can be carried out within the entire hierarchy if needed, so the user is protected from losing their place in the interface as happens with multiple windowed systems. This is especially so because Hyperbolic projections provide a *central focus* (the node in the centre of the window surrounded by the rest of the hierarchy in a shrunk form).
- *Direct Manipulation*: Each of the previous features is available in a direct manipulation manner, with the user not having to engage in slow dialogue-based interactions, but can instead traverse the graph to any point, without disengaging from the model that they are inspecting. This direct approach will increase

productivity via the removal of interaction steps, and is possible even on current entry level desktop and laptop machines. For instance, the demonstration software examples shown below for illustration purposes can be executed in real time on a standard Intel desktop machine, using the supplied OpenGL graphics solution. There are therefore no real impediments to this approach being utilised on modern entry level desktop and laptop machines.

- *Collaboration*: In the case of 3D virtual environments, there is a clear illustration of their power as collaborative process modelling environments, via the ability for more than one person to log into the 3D world in order to interact with and easily modify a process model. This has been exploited for many educational applications (e.g., Gallagher et al. 2005), but has not been explored in the BPM space. Large process models are often difficult to manipulate and model, so the provision of immersive worlds with real time interactive capabilities offers extended teamwork capabilities for remote modelling and interaction sessions.

User Interfaces for Large 3D Process Model Traversal

Using the concept of Hyperbolic projection and 3D Virtual Worlds as a process model representation, we now show how this approach can assist with each of the components that are important for large process model visualisation, viz., Zoom, Filter, Relationships, Context and Direct Manipulation, as described above. We show in Figure **3** an illustrative application of the above described interface features in action, on basis of a small prototype we have built by modifying source code developed by Munzner (1998). Our prototype shows a BPMN diagram loaded and presented for examination. The 3D Hyperbolic BPMN diagram is derived from a quality assurance process model available at: http://kswenson.wordpress.com/2008/01/01/human-process-trouble-ticket/.

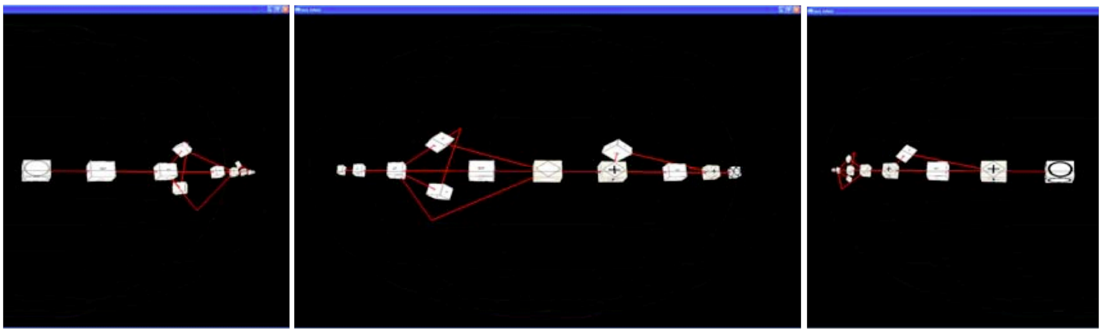

Figure 3: Illustration of the prototype manipulation interface, with a 3D Hyperbolic view showing a BPMN test diagram. The three views show the process model being traversed, illustrating the ability of the projection to show a curved view of the model, providing context and direct manipulation capabilities.

We have also implemented as a prototype a 3D virtual world process modelling tool, which is illustrated in Figure 4.

CONCLUSIONS

In this paper we have analysed the present state of the art in business process modelling software in dealing with large unified process models, based on criteria derived from user interaction and interface design literature. We found through our analysis that a lot of the advances in other applications of information visualisation have not been utilised in the business process modelling community.

We then presented a proposal to apply the hyperbolic graph and virtual world visualisation techniques available in interaction design to the context of enterprise-wide process model visualisation. We illustrated how this visualization approach can potentially enhance the understanding of the structure of the enterprise as a whole, due to its superior 3D layout capabilities. We suggested six key functionality that can facilitate advanced large process model interaction and visualisation: filtering, zoom, context, relationship, direct manipulation and collaboration. As a proof-of-concept, we developed preliminary prototypes to illustrate the proposed user interfaces. We expect tools that embody the identified features to facilitate more effective and efficient business process design, by supporting the end user community of systems, process and business analyst with advanced tool functionality in their process design work.

Our future work will involve improving the BPMN Hyperbolic process model viewer, and the virtual world representation. Usability testing will be performed to determine the abilities of the finished visualisation tools with large unified enterprise models gathered from industry level repositories. We will also investigate the integration of the two approaches, allowing the benefits of hyperprocess visualisations, and virtual worlds to be provided in a unified large process model interface in 3D.

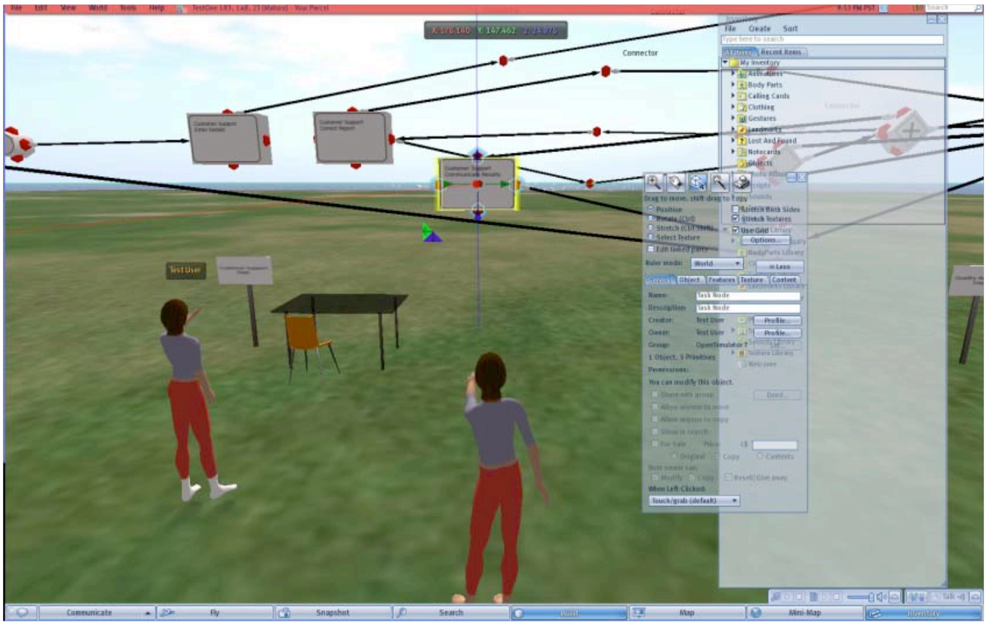

Figure 4 Illustration of a BPMN modelling tool in a 3D Virtual Environment, with an illustration of two avatars (representations of people logged into the world) collaborating in the environment in building the process model.

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